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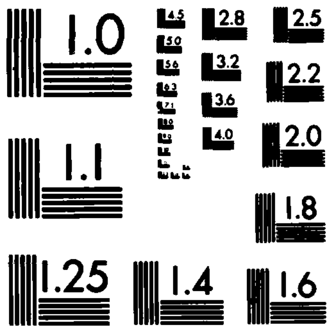
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TECHNICAL
MEMORANDUM
NCSC TM 359-82

NOVEMBER 1982

WATER QUALITY CONDITIONS IN ST ANDREW BAY NEAR THE NAVAL COASTAL SYSTEMS CENTER

DANIEL F. LOTT
HORACE G. LOFTIN

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NAVAL COASTAL SYSTEMS CENTER
NCSC
PANAMA CITY, FLORIDA 32407

NCSC TM 359-82

NAVAL COASTAL SYSTEMS CENTER

PANAMA CITY, FLORIDA 32407

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ADMINISTRATIVE INFORMATION

This report was prepared as an overhead function of the Naval Coastal Systems Center and constitutes a significant portion of the Center's environmental data base.

Released by
W. H. Tolbert, Head
Environmental Sciences Branch
September 1982

Under authority of
Max F. Dannecker, Head
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Water quality conditions in St. Andrew Bay adjacent to the Naval Coastal Systems Center during the period November 1973 to August 1977 are reported. Water temperature, salinity, turbidity, acidity, dissolved oxygen, biochemical oxygen demand, net primary productivity, total coliform bacteria, and total bacteria parameters were measured in three zones designated shore, grass, and channel. Water quality was considered excellent and with no indication of any appreciable adverse effects from Center operations.

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INTRODUCTION

The Naval Coastal Systems Center (NCSC) conducted a four-year survey of basic water quality condition in St. Andrew Bay adjacent to the Center (Figure 1). Sampling was carried out trimestrally from November 1973 through August 1977. The survey was designed to provide data for use in on-going research at NCSC.[1] However, its usefulness in identifying obvious or potential water quality problems and in providing a data base for water quality monitoring was recognized so that collecting stations and parameters were selected with this end also in mind.

This report describes the survey areas and methods used and provides a summary of findings for each water quality parameter investigated.

AREA DESCRIPTION

The St. Andrew Bay estuarine system is located in the northwest Gulf Coast of Florida between latitudes 30 degrees 00 minutes and 30 degrees 20 minutes North and longitudes 085 degrees 20 minutes and 085 degrees 53 minutes West. The system is comprised of four coastal plain bays: North Bay, West Bay, East Bay, and centrally, St. Andrew Bay. NCSC and Panama City are situated on St. Andrew Bay. Geologically, this estuarine system is an old stream valley which was flooded during the last major rise in sea level.[2] There are no major rivers feeding into the system so drainage input is small. This results in the system having salinities higher than in most other Florida Gulf estuaries; however, drainage input does not exceed evaporation, so the system is classified as a positive estuary.[3]

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[1] Naval Coastal Systems Center Technical Report TR 335-78, "Demonstration of a Virus Host System for Virus Removal Studies," by D. F. Lott, J. A. Braswell, and R. C. Dyjak, September 1978, UNCLASSIFIED.

[2] Curray, J. R., "Sediments and History of the Holocene Transgression, Continental Shelf, Northern Gulf of Mexico," Recent Sediments: Northwest Gulf of Mexico, Am. Assoc. Petrol. Geol., Tulsa, OK, 1960, pp. 221-266.

[3] Ichiye, T., and Jones, M. L., "On the Hydrography of the St. Andrew Bay System, Florida," Limn and Ocean, 1961, 61:302-311.

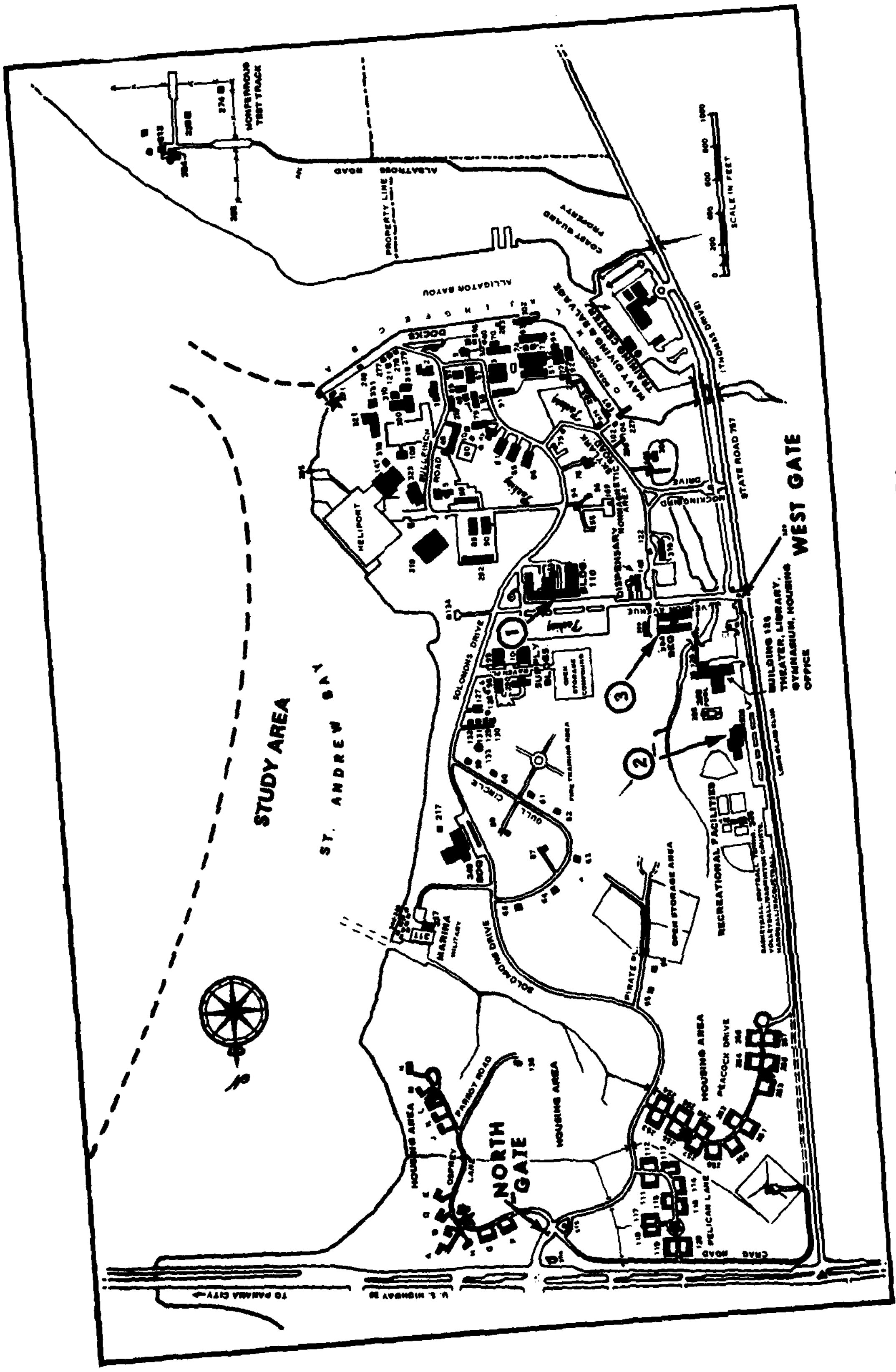

FIGURE 1. NCSC STUDY AREA

The water quality survey was conducted along the northwestern shore of St. Andrew Bay, adjacent to NCSC, at 37 collecting stations shown in Figure 2. The survey area was divided into three zones representing notable environmental differences in the area. Closest to the land is the shore zone with a mean high water depth of about 1 metre. At low water, especially during winter, this area may be exposed continuously for several hours. It is covered with fine to medium grained sand and contains no stands of marine grasses such as may be found in similar shallow water elsewhere in the system. It is probable that the protracted periods of exposure, particularly in cold weather, account for the absence of marine grasses.

From the edge of this zone and extending to water about 3 metres deep is the grass zone characterized by the presence of a broad, continuous band of marine grasses on the bottom. Beyond this depth and out to water about 10 metres deep is the channel zone which is devoid of marine grasses except at its inner edge. This area is most immediately subject to influence by the waters of the central bay.

On shore, two small creeks empty onto the survey area in the northern half of NCSC, a waste water treatment plant outfall is centrally located, and a small creek and smaller drain system are to the south. The northern two-thirds of the shore is generally park-like with some housing. The lower third is an industrial area with heliport, launching ramps, and docks at water's edge. At the end of the industrial area, Alligator Bayou opens to the bay; this bayou is faced with docks and shipping and its upper end receives effluent from a small creek draining an extensive civilian development including a commercial campsite with its own waste water treatment plant emptying effluent into the creek.

MATERIALS AND METHODS

Station positions were determined by use of bearings and permanent land marks; the station location was usually accurate to about 16 metres. Boat engines and anchors were used to maintain positions while collecting samples. Samples were collected between 0800 and 1200 hours each sampling day, regardless of tidal cycle.

Samples for the analysis of dissolved (DO), biochemical oxygen demand (BOD), turbidity (JTU), acidity (pH), and bacterial numbers were taken just below the surface with an 8-litre water sampler. Salinity and temperature were determined in-situ with a Beckman RS5-3 portable salinometer (accuracy ±0.3 ppt and ±0.5°C for salinity and temperature). The acidity (pH) was determined with an Orion Model 404 portable pH meter (accuracy ±0.05 pH units), and turbidity was determined with a Hach Model 2100A turbidiometer (accuracy ±0.02 JTU). Dissolved oxygen and biochemical oxygen demand were determined by two methods: (1) the modified Winkler method (accuracy ±0.05 ppm) and (2) a Yellow Springs Instrument Model 57

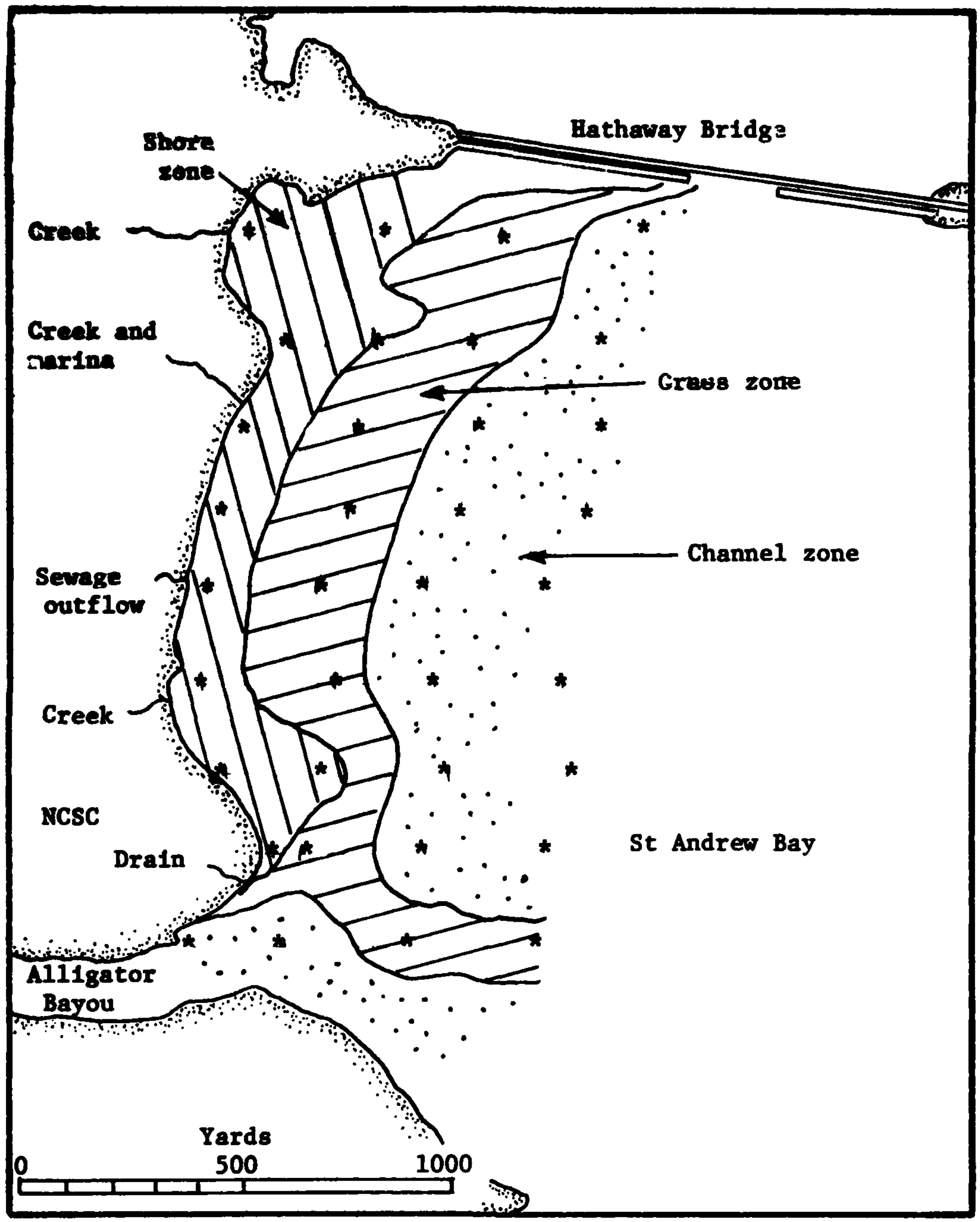

FIGURE 2. STUDY ZONES AND COLLECTING STATIONS IN ST. ANDREW BAY ADJACENT TO NCSC

Dissolved Oxygen Meter (accuracy ±0.05 ppm). Producitivity was determined by the light-and-dark-bottle method;[4] bottles were exposed for 4 hours per test and duplicates run with each station sampling.

Methods used to estimate bacteria included: (1) standard plate count for bacterial numbers and (2) membrane filtration for total coliforms. Techniques conformed to established procedures.[5]

RESULTS AND DISCUSSION

Thirteen surveys were conducted during the study period: November 1973; February, May, and September 1974; February, May, and September 1975; January, April, and August 1976; and April and August 1977. Thirty-seven stations in the study area were sampled (Figure 2). However, since the surveys were carried out principally in support of other research, the stations sampled varied considerably from survey to survey for each parameter. In analyzing these data, emphasis was placed on comparing parameter measurements from the three environmental zones found within the study area (shore, grass, and channel zones). If, for example, effluent from the waste water treatment plant emptying into the shore zone degraded some water quality parameter, then zonal comparisons might show this effect to influence or to be reduced by the other zones.

In the presentation of results for each parameter, measurements are reduced to seasonal and yearly averages for the three zones; and seasonal minima and maxima are given. The number of samples involved in each average is also presented. These sampling numbers merit attention because of the variations among samples due to rather wide-spread sampling dates. Appendix A contains survey means and averages that depict the seasonality of each parameter.

TEMPERATURE

Averages, minima, and maxima of surface water temperatures (°C) recorded in the shore, grass, and channel zones during the survey are shown in Table 1. Figure 3 shows monthly averages and ranges in the shore and channel zones, superimposed on curves of surface water temperature means and mean extremes from 30 years of data from Pensacola Bay.[6]

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[4]Slack, K. V., Averett, R. C., Greeson, P. E., and Lipscomb, R. G., "Methods for Collection and Analysis of Aquatic Biological and Microbiological Samples," Book 5, Chapter A4, Techniques of Water-Resource Investigation of the United States Geological Survey, 1973.

[5]Standard Methods of the Examination of Water and Waste Water, 14th Ed., APHA-AWWA-WPCF, 1975.

[6]US Coast and Geodetic Survey Spec. Pub No. 378, , "Surface Water Temperatures of Tide Stations Atlantic Coast North and South America," 1955.

TABLE 1

SEASONAL AND YEARLY SURFACE WATER TEMPERATURES FOR SHORE, GRASS, AND CHANNEL ZONES

Location		Temperature (°C)				
		Winter (Jan, Feb)	Spring (Apr, May)	Summer (Aug, Sep)	Fall (Nov, Dec)	Yearly
Shore Zone	Average	13.7	23.1	28.1	16.0	22.1
	Minimum	11.1	20.0	26.0	13.0	17.5*
	Maximum	18.0	26.7	30.0	22.1	24.2*
	(No. Samples)	(24)	(35)	(42)	(15)	
Grass Zone	Average	13.9	24.0	29.2	17.0	22.1
	Minimum	12.0	21.1	28.5	12.9	18.6
	Maximum	16.3	27.0	30.3	20.5	23.5
	(No. Samples)	(26)	(34)	(33)	(17)	
Channel Zone	Average	14.4	24.6	29.4	17.8	22.1
	Minimum	11.9	20.9	28.1	13.0	18.5
	Maximum	16.5	27.2	30.9	20.7	23.8
	(No. Samples)	(42)	(50)	(43)	(25)	

*The average of seasonal minima and maxima.

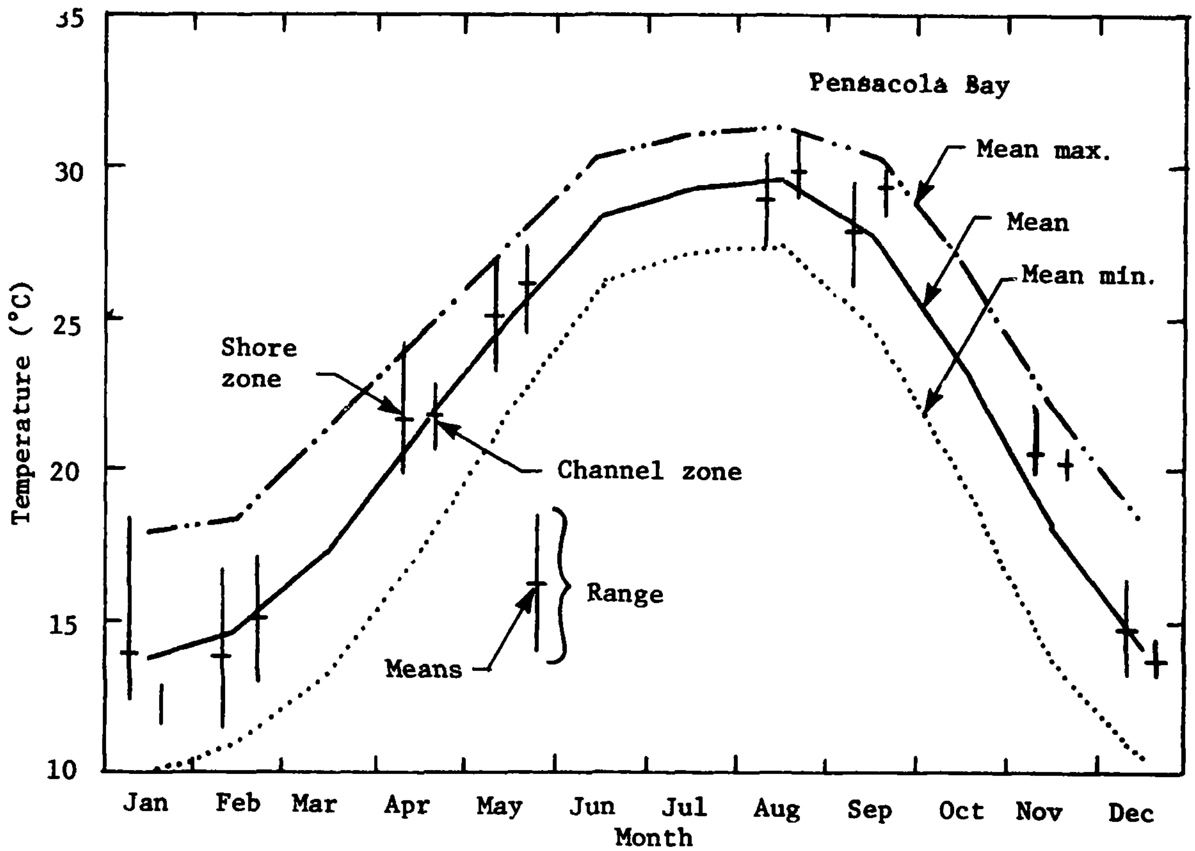

FIGURE 3. SURFACE WATER TEMPERATURES OF THE SHORE AND CHANNEL ZONES VERSUS PENSACOLA BAY 30-YEAR TEMPERATURE CURVES

In the absence of long-term water temperature data from St. Andrew Bay, the Pensacola Bay data are considered to be representative of expected local conditions.

Inspection of Figure 3 shows surface temperatures of the shore and channel zones to fit within normal limits set by the Pensacola Bay curves. Since grass and channel zone temperatures were similar (Table 1), all three zones had temperature means and ranges within expected limits for this area. There were no indications of unusual or adverse effects on water temperatures from discharges or other sources from NCSC or elsewhere.

As seen most clearly in Figure 3, temperature ranges were generally widest in the shore zone. This is to be expected, given the more immediate effects of insolation, wind, and air temperature on these very shallow waters. Further, run-off from the small creeks and waste water treatment plant outfall may be expected to add water of higher or lower temperatures to the shore zone, raising or lowering temperatures before these waters are mixed with those of the deeper, more heat-stable zones. Individual station data did not show the outfall station (Station 32) to vary significantly from other shore zone stations.

SALINITY

Averages, minima, and maxima of surface water salinity (in ppt) recorded in the shore, grass, and channel zones for each season and for the year are presented in Table 2. Averages and ranges are also given for the shore zone less the waste water treatment plant outfall (Station 32) as a special category.

While averages of all zones were fairly close, Table 2 shows that there was a trend toward reduced salinity from deepest to shallowest zones. Channel and grass zones were only slightly different in average salinity, with shore zone salinities notably less (2 to 3 ppt) than either. Ranges were uniformly widest in the shore zone due to the much lower salinities recorded there.

Fresh water effluent discharged from the waste water treatment plant was an obvious contributor to the lower salinities encountered in the shore zone. Comparison of salinity averages and ranges in the shore zone versus the shore zone less the outfall station (Table 2) shows that in every case the lowest salinities occurred at the outfall station. Seasonally, average salinities were 0.4 to 0.8 ppt higher with the omission of the outfall station. However, the outfall contribution had only a localized effect on shore zone salinities in general. Fresh water from three small creeks plus general runoff from land probably exerted more influence on average shore zone salinities than did the outfall. This is seen in the shore-zone-less-outfall averages and minima (Table 2), covering the entire shore area, which still had salinities notably less than those of the deeper water zones. In any event, the fresh water contributions of the shore zones were scarcely detectable in the grass and channel zones.

TABLE 2

SEASONAL AND YEARLY SURFACE WATER SALINITIES
FOR SHORE, GRASS, AND CHANNEL ZONES

		Water Salinity (ppt)				
Location		Winter (Jan, Feb)	Spring (Apr, May)	Summer (Aug, Sep)	Fall (Nov, Dec)	Yearly
Shore Zone	Average	21.7	23.8	22.4	23.8	22.8
	Minimum	1.0	12.0	6.0	15.0	8.5*
	Maximum	27.4	28.7	30.1	29.2	28.9*
	(No. Samples)	(33)	(36)	(44)	(21)	
Shore Zone Less Treatment Plant Station	Average	22.4	24.2	23.2	24.6	23.5
	Minimum	12.0	17.0	14.0	20.0	15.8
	Maximum	27.4	28.7	30.1	29.2	28.9
	(No. Samples)	(30)	(33)	(40)	(19)	
Grass Zone	Average	24.0	24.8	25.1	26.6	25.0
	Minimum	22.4	21.1	19.0	23.3	21.4
	Maximum	26.0	28.9	30.9	29.5	28.8
	(No. Samples)	(26)	(34)	(33)	(17)	
Channel Zone	Average	24.1	25.2	26.3	27.4	25.6
	Minimum	22.5	21.2	19.0	22.3	21.3
	Maximum	27.0	30.0	31.0	29.6	29.4
	(No. Samples)	(40)	(50)	(43)	(26)	

*The average of seasonal minima and maxima.

Ichiye and Jones[3] reported salinity measurements taken hourly over 24 hours on each of three days (November 1957, March and September 1958) at a station in the channel near the survey area. Their average salinities on these dates were 22.1, 20.9, and 25.9 ppt. They also noted considerable fluctuation in salinities within 24-hour cycles. For example, surface salinities in the November 1957 series varied from 22.0 to 30.0 ppt. They stated that salinity changes in St. Andrew Bay were, on the whole, probably caused by tidal currents; however, stationary currents from surface wind drift or drainage may overbalance the periodic tidal change. They ascribed the continuous rise of salinity seen in the November 1957 test, which began at 22 ppt, to persistent flood currents due to persistent southerly winds present through that 24-hour period.

TURBIDITY

Averages, minima, and maxima of turbidity levels (JTU) recorded in the shore, grass, and channel zones for each season and for the year are presented in Table 3. Turbidity averages for each station taken through the survey period are shown in Figure 4.

Little difference can be noted in averages and ranges of turbidity between grass and channel zones. Shore zone turbidities, however, averaged higher and maxima were nearly double or more those of the deeper water zones. Highest turbidity levels were encountered at the waste water treatment plant outfall station in all four seasons (Table 3), while the average of all turbidities determined at the outfall station was more than twice the average of any other station in the shore zone (Figure 4).

Effluent at the outfall station may be expected to contain particulate matter which would increase turbidity to some degree. However, periodic inspection of the effluent as it leaves the outfall has shown it consistently to be of remarkable clarity. Undoubtedly, there are episodes in the operation of the treatment plant in which more particulates are emitted. It is likely, though, that the turbidities recorded at the outfall station were due in large part to stirring of bottom sediments by the appreciable force of the existing effluent there. The effect of outfall turbidity is apparently very localized (Figure 4).

The relatively high turbidities of the shore zone (other than at the outfall station) may be accounted for largely by wave and tidal action on the shallow bottom and from creek outflow and sheetwash from the land. However, in practical terms, all levels of turbidity recorded in this survey are low and are indicative of very clear water generally. Even the few instances of individual turbidities between 5.0 and 7.0 JTU are well within good turbidity levels of most Gulf Coast estuarine situations. (Florida water quality standards state that turbidity shall not exceed 50 JTU.)

While average turbidities were similar between the deeper grass and shore zones (Table 3), the averages of all turbidity readings taken for

TABLE 3

SEASONAL AND YEARLY SURFACE WATER TURBIDITIES
FOR SHORE, GRASS, AND CHANNEL ZONES

Location		Surface Water Turbidity (JTU) Winter (Jan, Feb)	Spring (Apr, May)	Summer (Aug, Sep)	Fall (Nov, Dec)	Yearly
Shore Zone	Average	1.6	1.0	2.1	1.1	1.5
	Minimum	0.4	0.3	0.4	0.6	0.4*
	Maximum	7.0**	2.8**	5.1**	3.1**	4.5*
	(No. Samples)	(32)	(44)	(44)	(22)	
Grass Zone	Average	0.9	0.6	1.1	0.7	0.8
	Minimum	0.3	0.3	0.4	0.6	0.4
	Maximum	1.8	1.1	2.6	0.9	1.6
	(No. Samples)	(26)	(34)	(33)	(17)	
Channel Zone	Average	0.9	0.5	0.9	0.7	0.8
	Minimum	0.3	0.3	0.4	0.5	0.4
	Maximum	2.1	0.8	1.5	1.2	1.4
	(No. Samples)	(42)	(50)	(42)	(24)	

*The average of seasonal minima and maxima.
**Turbidity level at outfall station.

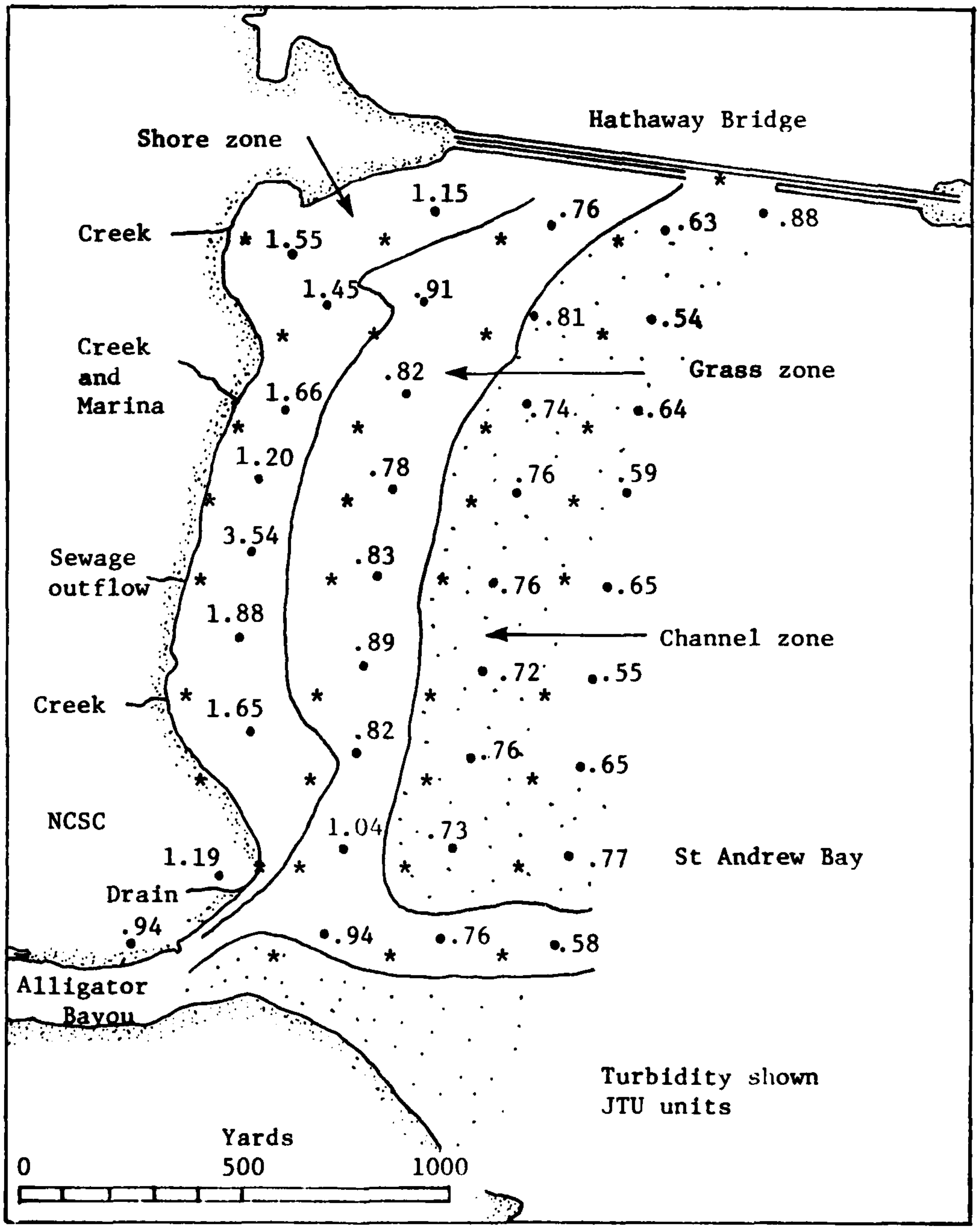

FIGURE 4. AVERAGE TURBIDITY LEVELS AT EACH STATION DURING THE SURVEY

each station suggest a trend toward decreasing turbidity with distance from shore. This may be seen in Figure 4 in each of the four columns of stations from shore outward showing progressively lower turbidity levels in general.

ACIDITY

Averages, minima, and maxima of acidity (pH) in the shore, grass, and channel zones for each season and for the year are shown in Table 4.

The pH levels in the grass and channel zones were similar in the survey period (Table 4). Shore zone pH levels differed from those of the deeper zones only in the occurrence of lower minima. With few exceptions, the lowest pH records were from the outfall station (Station 32), reflecting the high chlorine content of the treated effluent. At adjacent stations, pH was generally at normal levels detected at other stations, indicating the rapid dilution of the outfall station effluent.

Florida water quality standards limit pH of saline waters to a range of 6.5 to 8.5. The minimum limit was not violated during this survey. However, the maximum limit was exceeded in all three zones (pH of 8.8 to 8.9) in May 1975 and once in the shore zone (pH of 8.6) in August 1976. There were no known effluents or other natural or man-made sources from NCSC or elsewhere to account for these episodes.

DISSOLVED OXYGEN

Averages, minima, and maxima of dissolved oxygen in surface water (mg/ℓ) in the shore, grass, and channel zones for each season and for the year are shown in Table 5.

Table 5 shows that there was little appreciable difference in dissolved oxygen concentration within the three zones for each season and that they fell within expected limits for seasonal water temperatures. There was a trend toward slightly higher dissolved oxygen in the shore zone in colder months. This might be accounted for by more vigorous aeration from wind and wave action and effects of low air temperatures in this shallowest zone. However, the difference between this and the other zones was not marked.

Dissolved oxygen concentrations at the outfall station (Station 32) were generally as high or higher than at other shore zone stations on all sampling dates. This attests to the high quality of effluent from the NCSC waste water treatment plant. Florida water quality standards require that dissolved oxygen concentrations shall not average less than 5.0 mg/ℓ in a 24-hour period or be less than 4.0 mg/ℓ in any sample. In the entire 4-year survey, there was only one determination of dissolved oxygen below 5.0 mg/ℓ; i.e., 4.6 mg/ℓ at one channel zone station in May 1977.

TABLE 4

SEASONAL AND YEARLY SURFACE WATER ACIDITY DETERMINATIONS
FOR SHORE, GRASS, AND CHANNEL ZONES

		Acidity (pH)				
Location		Winter (Jan, Feb)	Spring (Apr, May)	Summer (Aug, Sep)	Fall (Nov, Dec)	Yearly
Shore Zone	Average	8.2	8.3	8.1	8.2	8.2
	Minimum	6.9	7.8	7.3	8.0	7.5*
	Maximum	8.3	8.8	8.6	8.5	8.5*
	(No. Samples)	(32)	(36)	(42)	(22)	
Grass Zone	Average	8.2	8.3	8.2	8.2	8.2
	Minimum	8.1	8.0	7.8	8.1	8.0
	Maximum	8.3	8.8	8.5	8.3	8.5
	(No. Samples)	(26)	(34)	(33)	(15)	
Channel Zone	Average	8.2	8.3	8.2	8.2	8.2
	Minimum	8.0	8.0	7.9	8.2	8.0
	Maximum	8.3	8.8	8.5	8.3	8.5
	(No. Samples)	(41)	(43)	(44)	(20)	

*The average of seasonal minima and maxima.

TABLE 5

SEASONAL AND YEARLY SURFACE WATER DISSOLVED OXYGEN CONCENTRATIONS FOR SHORE, GRASS, AND CHANNEL ZONES

		Dissolved Oxygen (mg/ℓ)				
Location		Winter (Jan, Feb)	Spring (Apr, May)	Summer (Aug, Sep)	Fall (Nov, Dec)	Yearly
Shore Zone	Average	9.3	7.6	6.6	9.1	7.9
	Minimum	8.6	6.6	5.9	7.7	7.2*
	Maximum	10.3	10.3	7.9	9.9	9.6*
	(No. Samples)	(12)	(16)	(16)	(8)	
Grass Zone	Average	9.0	7.2	6.8	8.6	7.5
	Minimum	8.5	6.3	6.2	7.3	7.1
	Maximum	9.4	7.8	9.1	9.7	9.0
	(No. Samples)	(10)	(26)	(26)	(13)	
Channel Zone	Average	8.9	6.9	7.3	9.1	7.8
	Minimum	8.5	4.5	5.9	8.0	6.7
	Maximum	9.5	7.7	9.1	9.6	9.0
	(No. Samples)	(11)	(20)	(20)	(10)	

*The average of seasonal minima and maxima.

BIOCHEMICAL OXYGEN DEMAND

Averages, minima, and maxima of surface water biochemical oxygen demand (BOD) in the shore, grass, and channel zones for each season and for the year are presented in Table 6.

In contrast to the other parameters, BOD levels in the grass and channel zones were not essentially similar. The channel zone BOD was slightly higher than the grass zone BOD, while the grass and shore zone BOD levels were generally close (Table 6). However, the BOD was measured at only one channel zone station so that determinations there may not be representative. In any case, the differences noted were only in the range of ±1.0 mg/ℓ of BOD. The shore zone BOD average for winter was relatively high due to a single BOD determination of 8.2 mg/ℓ at the outfall station, probably the result of an episode of higher organic matter concentration from the effluent. Other than another high of 5.2 mg/ℓ BOD there in summer, BOD at the outfall station was in the range of other shore zone stations.

All of these BOD levels, even the highest, are modest compared to BODs that may be expected in many or most Gulf estuarine situations. Florida water quality standards state that BOD shall not exceed values that would depress dissolved oxygen concentrations below acceptable levels. Table 5 (DO concentration) shows that the BODs encountered in the test area did not materially affect the generally high DO levels of each zone.

NET PRIMARY PRODUCTIVITY

Averages of surface water net primary productivity (mg $O_2/m^3/hr$) in the shore, grass, and channel zones for each season and for the year are shown in Table 7; averages for the shore zone (less the outfall station) are also given.

The productivity of water bodies is a function of a wide range of environmental factors such as available nutrients, circulation, temperature, duration and intensity of sunlight, and opacity of the water. Thus, productivity is an integrator of environmental conditions, making it useful as a general water quality indicator. A standard measure of productivity is the quantity of oxygen produced by photosynthetic plankton in excess of respiration oxygen consumed; i.e., net primary productivity. This may be expressed as milligrams of oxygen produced per cubic metre of water per unit of daylight time.

Table 7 shows that the shore zone was subtantially less productive than the grass or channel zones in all seasons except summer. Grass and channel zones were similar in all seasons with perhaps a trend toward slightly higher productivity in the channel zone.

A considerable proportion of the lower productivity of the shore zone is apparently due to waste water treatment plant effluent. Net productivity

TABLE 6

SEASONAL AND YEARLY SURFACE WATER BIOCHEMICAL OXYGEN DEMANDS FOR SHORE, GRASS, AND CHANNEL ZONES

		Biochemical Oxygen Demands (mg/ℓ)				
Location		Winter (Jan, Feb)	Spring (Apr, May)	Summer (Aug, Sep)	Fall (Nov, Dec)	Yearly
Shore Zone	Average	2.5	1.8	1.8	1.9	2.0
	Minimum	1.2	1.3	0.9	1.1	1.1*
	Maximum	8.2	2.7	5.2	2.8	4.7*
	(No. Samples)	(12)	(16)	(16)	(8)	
Grass Zone	Average	1.9	1.7	1.9	1.7	1.8
	Minimum	0.9	1.2	0.7	0.7	0.9
	Maximum	2.9	2.3	4.0	2.3	2.9
	(No. Samples)	(15)	(20)	(20)	(10)	
Channel Zone	Average	2.6	3.5	3.2	2.4	3.0
	Minimum	1.5	2.2	1.8	1.6	1.8
	Maximum	3.3	4.3	4.1	3.1	3.7
	(No. Samples)	(3)	(4)	(4)	(2)	

*The average of seasonal minima and maxima.

TABLE 7

SEASONAL AND YEARLY SURFACE WATER NET PRIMARY PRODUCTIVITY FOR SHORE, GRASS, AND CHANNEL ZONES

	Average Net Primary Productivity ($mgO_2/m^3/hr$)				
Location	Winter (Jan, Feb)	Spring (Apr, May)	Summer (Aug, Sep)	Fall (Nov, Dec)	Yearly
Shore Zone	-18.8	42.1	119.6	-62.5	20.1
Shore Zone (without Outfall Station)	-47.4	55.9	181.3	5.4	48.8
Grass Zone	6.8	80.7	105.7	77.3	67.6
Channel Zone	8.2	65.7	125.7	106.3	76.5

of the shore zone (less the outfall station) is compared with that of all the shore zone stations (Table 7). In three of the four seasons, exclusion of the outfall station yielded notably higher average productivity. The exception, noted in winter, was due to one anomalous episode of high productivity of 200 mg $O_2/m^3/hr$. It is likely that the high chlorine content of this effluent, which was adequate to kill bacteria and phytoplankton, was largely responsible for depressed productivity at the outfall station.

Even after discounting the outfall effects, the shore zone stations remained considerably lower in productivity in cooler months than those of the other zones. This then may be related to more variable environmental conditions, such as temperature and salinity as discussed above. Summer conditions, when environmental conditions are generally optimal for plankton, resulted in more or less uniformly high productivity in all zones. Net productivity throughout reflects cyclic rise and fall with increasing and decreasing temperature and sunlight, according to season.

TOTAL COLIFORM BACTERIA

Geometric averages, minima, and maxima of total coliform bacteria counts (TC/100 mℓ) in surface waters of the shore, grass, and channel zones are presented in Table 8.

Total coliform bacteria (TC) comprise a group of bacteria from the gut of warm-blooded animals, i.e., birds and mammals, including man, and also non-fecal (usually soil) sources. Thus, TC can be expected in surface waters exposed to soil runoff and to wildlife. When TC concentrations reach arbitrary high levels, they are then considered to indicate possible human fecal contamination and thus constitute a possible health hazard. Pertinent Florida water quality standards, i.e., for Class 3 waters, state that TC counts shall not (1) exceed a geometric average of 1000 TC/100 mℓ of sample per month, (2) exceed 1000/100 mℓ in more than 20 percent of samples during any month, and (3) exceed 2400/100 mℓ in any sample.

Data presented in Table 8 and analysis of monthly data show that the survey waters adjacent to NCSC met Florida standards for total coliform bacteria counts with only minor and sporadic exceptions. First, TC monthly geometric averages in all three zones were low (the highest being 173/100 mℓ in the shore zone) so that the criterion for monthly average was met. Secondly, only in September 1974 was there an incident of 20 percent of samples greater than 1000/100 mℓ, again in the shore zone. And thirdly, and involving the same samples of the September 1974 bacteria count, three of 22 shore zone samples in that month had TC counts in excess of 2400/100 mℓ (viz., 3000, 3700, and 6250/100 mℓ).

Since the NCSC waste water treatment plant effluent empties into the shore zone at Station 32, the plant outfall would immediately be suggested as the point source of those high TC concentrations. However, TC counts

TABLE 8

SEASONAL AND YEARLY SURFACE WATER TOTAL COLIFORM BACTERIA COUNTS FOR SHORE, GRASS, AND CHANNEL ZONES

		Coliform Bacteria (TC/100 mℓ)				
Location		Winter (Jan, Feb)	Spring (Apr, May)	Summer (Aug, Sep)	Fall (Nov, Dec)	Yearly
Shore Zone	Geometric Average	3	15	16	14	10
	Minimum	0	0	0	2	1*
	Maximum	700	2100	6250	200	1164*
	(No. Samples)	(33)	(41)	(44)	(13)	
Grass Zone	Geometric Average	6	2	19	19	8
	Minimum	0	0	0	4	1
	Maximum	500	100	600	200	278
	(No. Samples)	(15)	(20)	(20)	(7)	
Channel Zone	Geometric Average	0	5	24	37	8
	Minimum	0	0	0	10	2
	Maximum	500	100	1850	140	337
	(No. Samples)	(5)	(12)	(12)	(3)	

*Geometric average of seasonal minima and maxima.

of the outfall were within standards; the excessive counts occurred elsewhere in the shore zone and at some distance from the outfall. It is likely that those high TC concentrations reflected surface drainage from creeks and runoff rather than unacceptable point source pollution from the treatment plant. During this same period (September 1974), high concentrations of total bacteria (see next section) were recorded from the shore zone which suggested a heavy contribution of runoff water into the area at that time. Otherwise, TC maxima for each month and season indicated generally good quality for the treatment plant effluent and its mixing zone in the shore zone.

TOTAL BACTERIA

Geometric averages, minima, and maxima of total bacteria counts (bacteria/mℓ) in surface waters of the shore, grass, and channel zones are presented in Table 9.

Total bacteria (in contrast to total coliform bacteria) are not in themselves indicators of water quality. The total bacterial count simply represents the number of bacteria of all kinds in an aliquot of water that can live and multiply under given laboratory conditions. They are, however, an indirect measure of water quality or environmental conditions of the water in that bacterial numbers reflect organic content, temperature, and other environmental features that affect water quality.

Table 9 shows a general similarity of total bacteria counts in all seasons between grass and channel zones. Shore zone counts are usually higher as shown by the 3 to 1 ratio of shore zone and grass or channel zone averages.

The greater bacterial numbers in shore zone water may be accounted for in large part by the more intensive mixing of bottom-dwelling bacteria into the water column in this shallow area. Likewise, terrestrial bacteria entering the shore zone from land drainage should increase the total count there. Terrestrial bacteria are not competitive in saline waters and are soon removed by absorption, settling, predation, and bactericidal action of the sea water.[7] [8] [9] [10] Hence, their numbers should decrease rapidly with distance from the shore. There was no noticeable bacterial addition to the shore zone from the treatment plant station where the count was usually below the maximum numbers reported in Table 9.

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[7]Carlucci, A. F. and Pramer, D., "Factors Affecting the Survival of Bacteria in Sea Water," Appl. Microbiol. 1959, 7:388-392.

[8]Mitchell, R., "Factors Affecting the Decline of Non-Marine Micro-Organisms in Sea Water," Water Res., 1968, 2:535-543.

[9]Zobell, C. E., "Bactericidal Action of Sea Water," Proc. Soc. Exptl. Biol., Med. 1936, 34:113-116.

[10]Waksman, S. A. and Hotchkiss, M., "Viability of Bacteria in Sea Water," J. Bact., 1937, 33:381-400.

TABLE 9

SEASONAL AND YEARLY SURFACE WATER TOTAL BACTERIA COUNTS
FOR SHORE, GRASS, AND CHANNEL ZONES

		Bacteria Count (Bacteria/mℓ)				
Location		Winter (Jan, Feb)	Spring (Apr, May)	Summer (Aug, Sep)	Fall (Nov, Dec)	Yearly
Shore Zone	Geometric Average	42	182	761	17	100
	Minimum	0	6	6	2	3*
	Maximum	1760	1735	27,450	395	2400*
	(No. Samples)	(32)	(44)	(44)	(17)	
Grass Zone	Geometric Average	19	35	134	10	31
	Minimum	11	6	5	2	5
	Maximum	50	123	57,000	21	293
	(No. Samples)	(15)	(20)	(20)	(10)	
Channel Zone	Geometric Average	11	58	124	12	31
	Minimum	0	1	4	3	2
	Maximum	35	123	2335	27	128
	(No. Samples)	(6)	(12)	(12)	(4)	

*Geometric average of seasonal minima and maxima.

Total bacterial counts recorded in this survey were low compared to Gulf estuarine waters in general. This probably reflects the low levels of suspended matter in the survey waters (e.g., Table 3, Turbidity). However, these counts tend to be underestimates of actual bacterial numbers since the plating medium and incubating methods will significantly affect laboratory results.[11] [12] This, along with morphological forms and physiological peculiarities of different bacterial species, makes laboratory counts empirical at best.[13]

SUMMARY AND DISCUSSION

Tables 1 through 9 show seasonal and yearly averages and ranges of nine water quality parameters investigated in shore, grass, and channel zones of St. Andrew Bay adjacent to NCSC. Table 10 summarizes the yearly average and range for each of the parameters in the three zones.

For all parameters except BOD and productivity, grass and channel zones were essentially similar so that determinations from the one zone may be taken as representative of the other for those parameters. BOD and productivity measurements, however, were so distinct that separate measurements should be made from each zone for these parameters. Shore zone parameters were all sufficiently distinct from the other zones to require separate measurement in all cases.

The shore zone, extending from the shore to the inner margin of the grass flats at about 1-metre depth, is subject to greater environmental variation than the other zones. First, shallowness of the water increases the effects of insolation, air temperature, and wave and wind action. The bottom is easily stirred here, adding sediment and other materials to the water column. It receives land water runoff from three small creeks and from sheetwash. In addition, it receives at a point source 150,000 gallons per day of effluent from the NCSC waste water treatment plant. Treatment plant records show that the effluent produced is of relatively very good quality; BOD, settlable solids, and bacterial counts are all very low. This is reflected in the results of this survey. While the influence of the effluent was detectable at the outfall station (Station 32), effects in this mixing zone were genuinely modest. Away from this station, measurable effects were scarcely present.

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[11] Jannasch, H. W. and Jones, G. E., "Bacterial Populations in Sea Water as Determined by Different Methods of Enumeration," Limn. and Oceangr., 1959, 4:128-139.

[12] Jannasch, H. W., "Biological Significance of Bacterial Counts in Aquatic Environments," Proc. Atmos. Biol. Conf., 1965, pp 127-131.

[13] Zobell, C. E., Marine Microbiology, Chronica Botanica Publishing Co., Waltham, Mass. 1946.

TABLE 10

YEARLY AVERAGE AND AVERAGE EXTREMES OF WATER QUALITY PARAMETERS OF ST. ANDREW BAY ADJACENT TO NCSC

	Shore Zone			Grass Zone			Channel Zone		
Parameters	Yearly Average	Yearly Average Minimum	Yearly Average Maximum	Yearly Average	Yearly Average Minimum	Yearly Average Maximum	Yearly Average	Yearly Average Minimum	Yearly Average Maximum
Temperature (°C)	22.1	17.5	24.2	22.1	18.6	23.5	22.1	18.5	23.8
Salinity (ppt)	22.8	8.5	28.9	25.0	21.4	28.8	25.6	21.3	29.4
Turbidity (JTU)	1.5	0.4	4.5	0.8	0.4	1.6	0.8	0.4	1.4
Acidity (pH)	8.2	7.5	8.5	8.2	8.0	8.5	8.2	8.0	8.5
Dissolved Oxygen (DO) (mg/ℓ)	7.9	7.2	9.6	7.5	7.1	9.0	7.8	6.7	9.0
Biochemical Oxygen Demand (BOD) (mg/ℓ)	2.0	1.1	4.7	1.8	0.9	2.9	3.0	1.8	3.7
Productivity (mg $O_2/m^3/hr$)	20.1	-	-	48.8	-	-	67.6	-	-
Total Coliform* (TC/100 mℓ)	10	1	1164	8	1	278	8	2	337
Total Bacteria* (Bacteria/mℓ)	100	3	2400	31	5	293	31	2	128

*Geometric averages

It is concluded that the waters of St. Andrew Bay adjacent to NCSC north of Alligator Bayou are of good to excellent water quality and show no indication of any appreciable adverse effect from activities on shore at NCSC. Rather, water quality there reflects the natural state of the bay in general, which is the dominant influence. The data presented in this report constitute a sound data base from which the water quality off NCSC can be measured in the future.

APPENDIX A

SURVEY MEANS AND AVERAGES

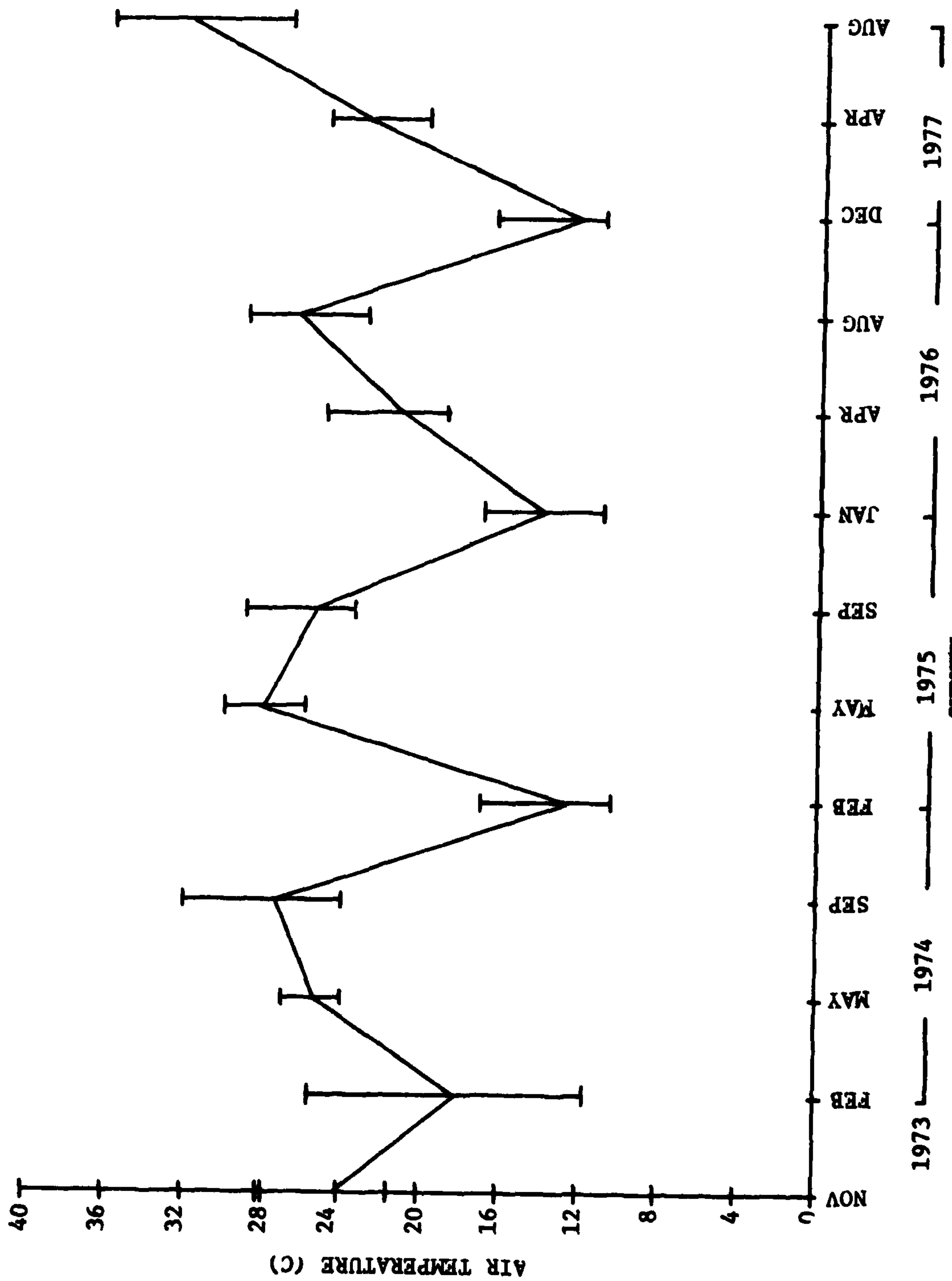

FIGURE A1. AIR TEMPERATURES

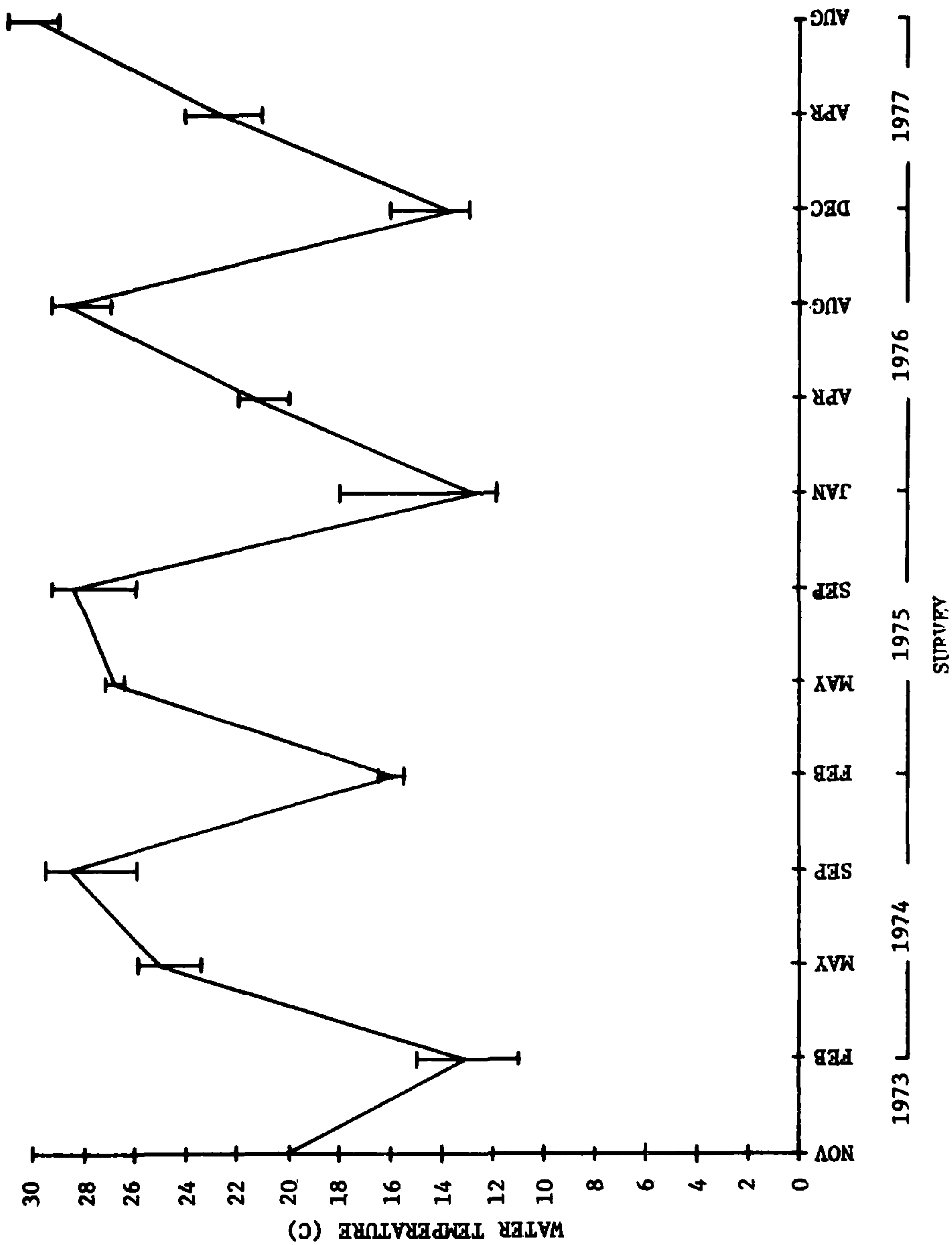

FIGURE A2. WATER TEMPERATURES

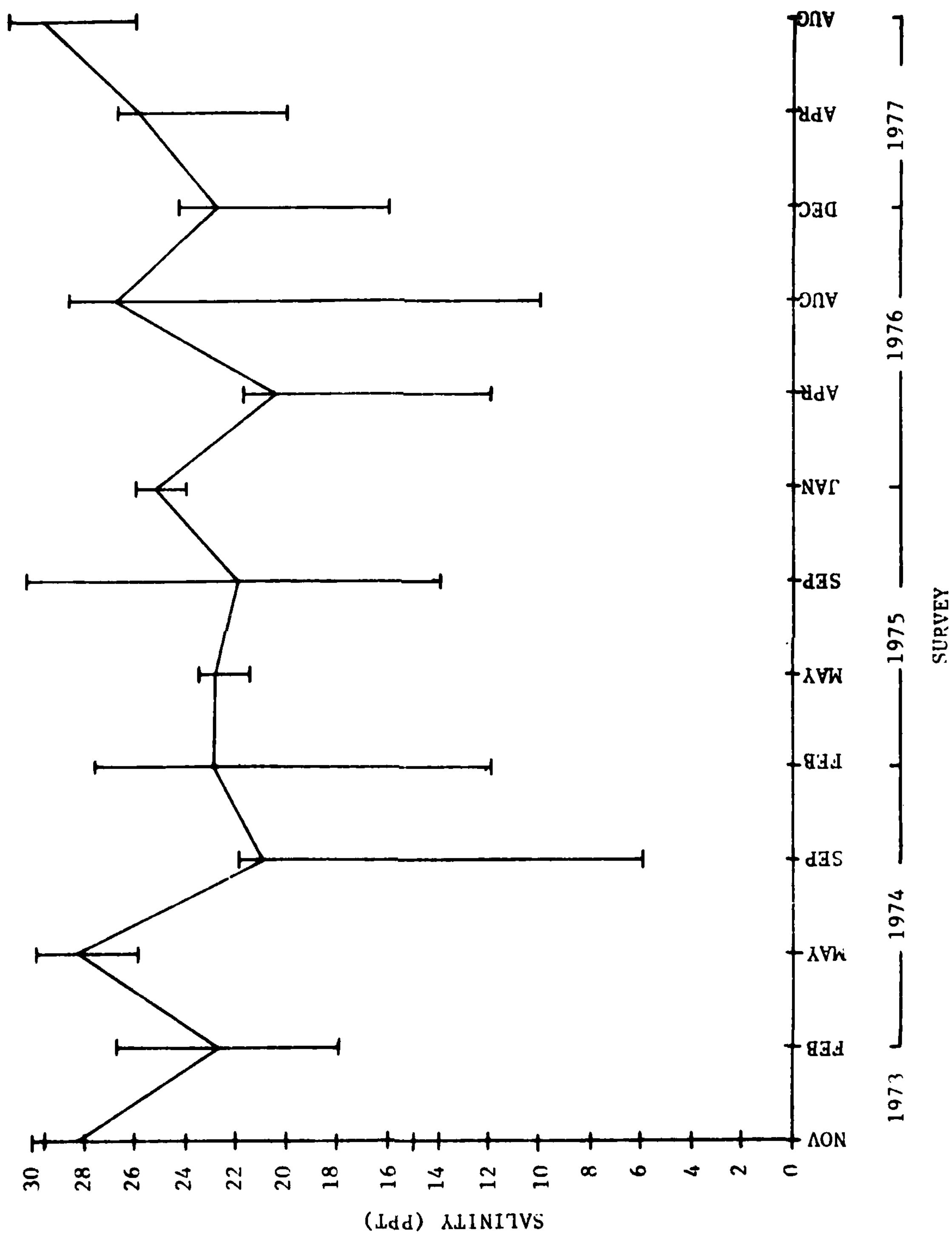

FIGURE A3. SALINITY

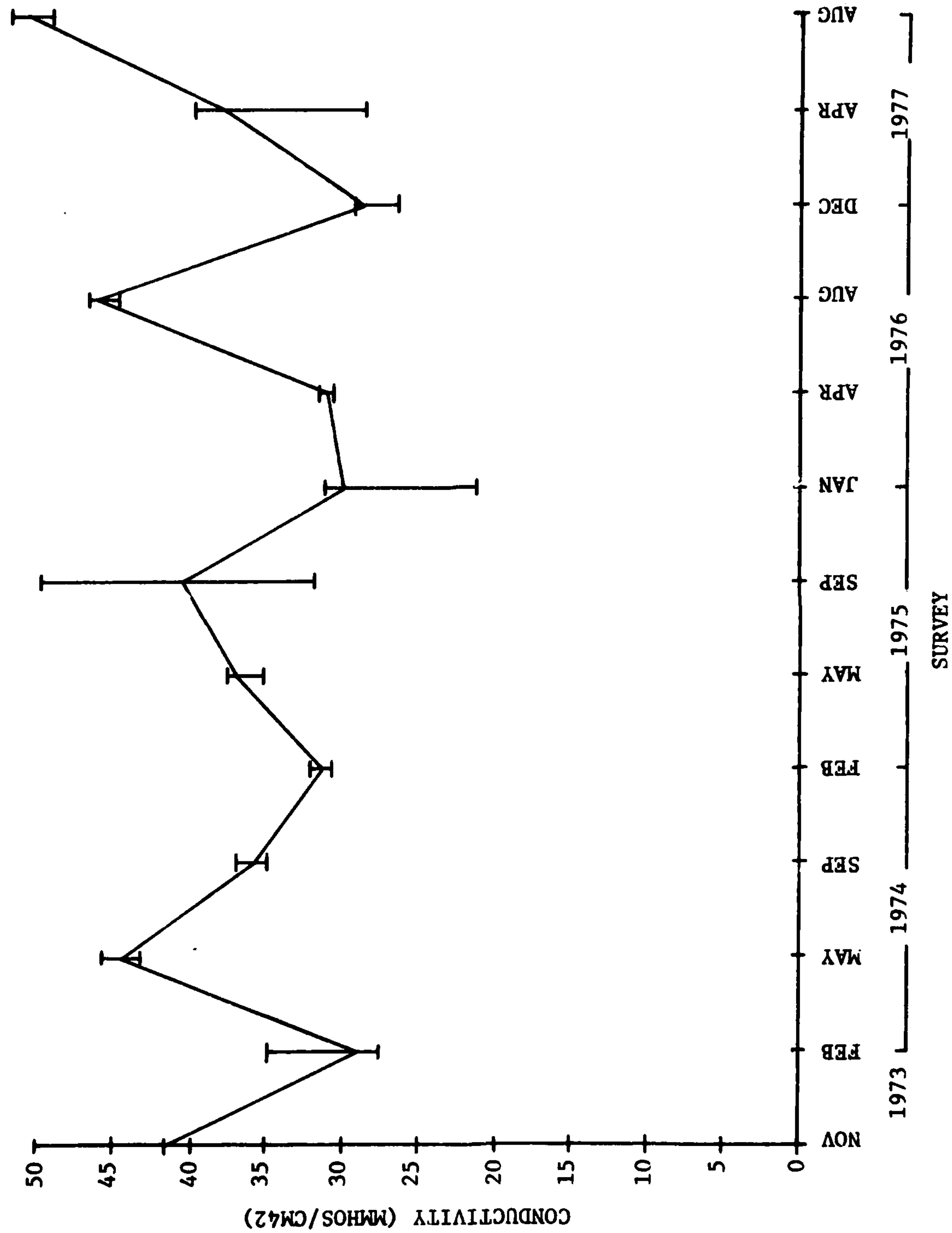

FIGURE A4. CONDUCTIVITY

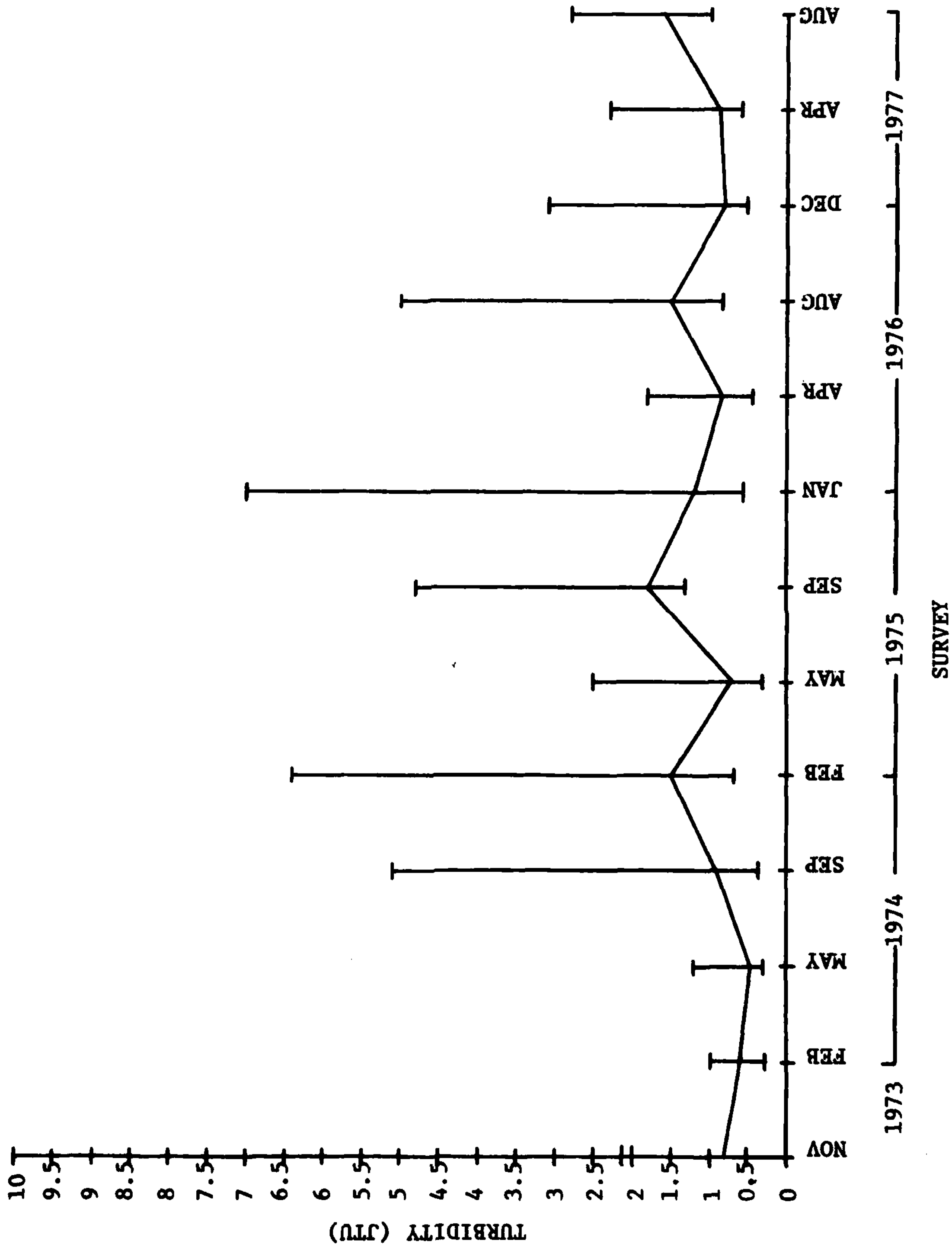

FIGURE A5. TURBIDITY

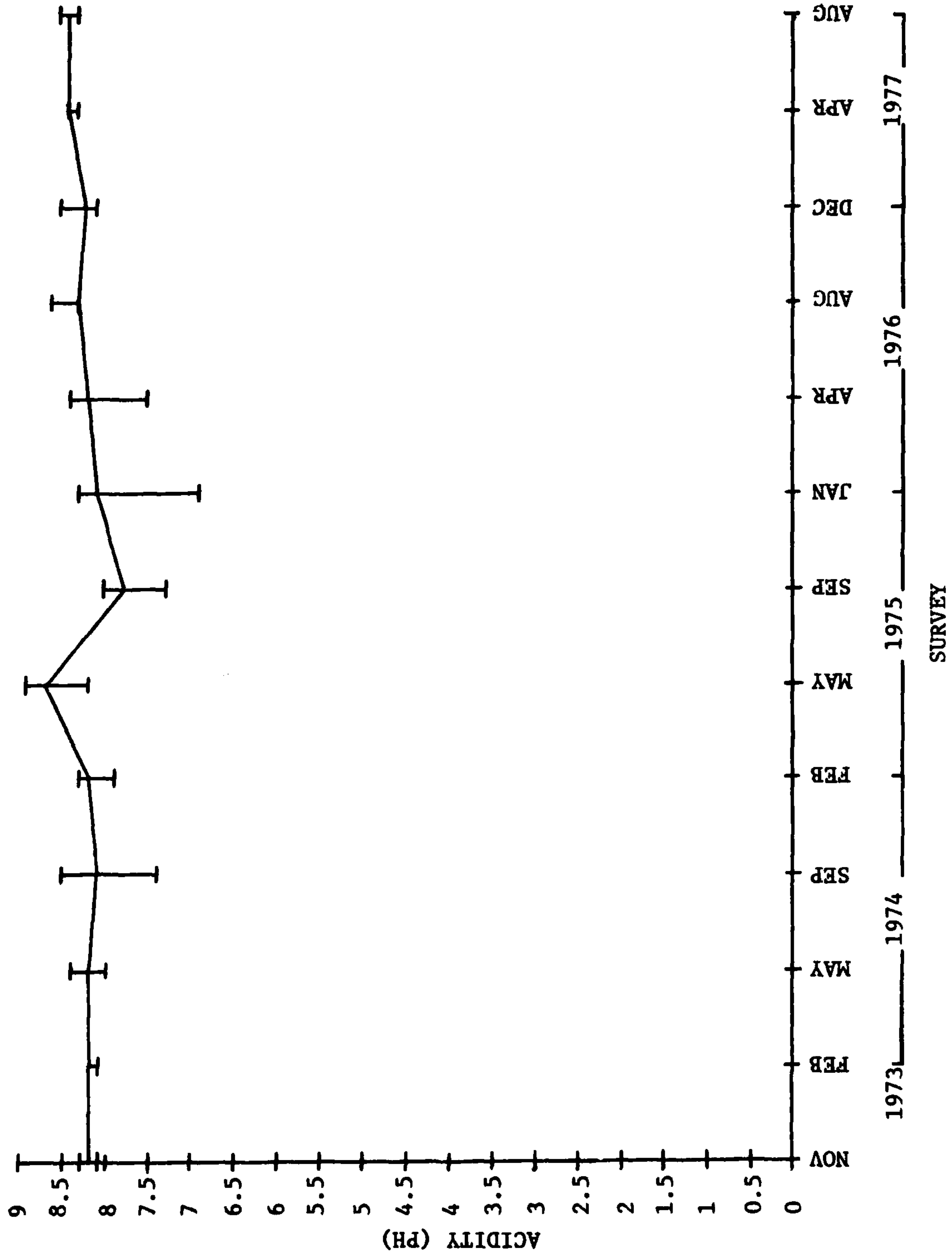

FIGURE A6. ACIDITY

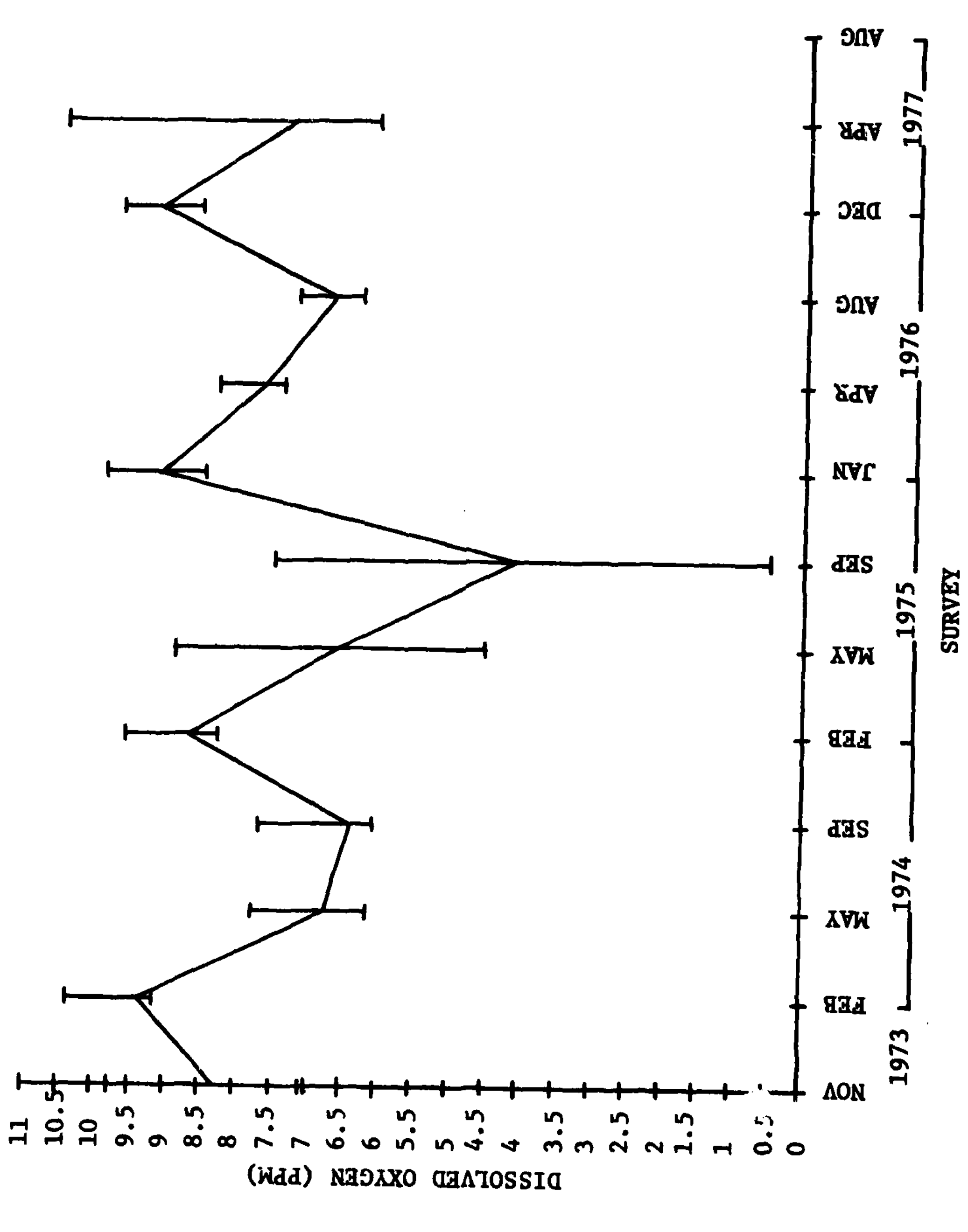

FIGURE A7. DISSOLVED OXYGEN

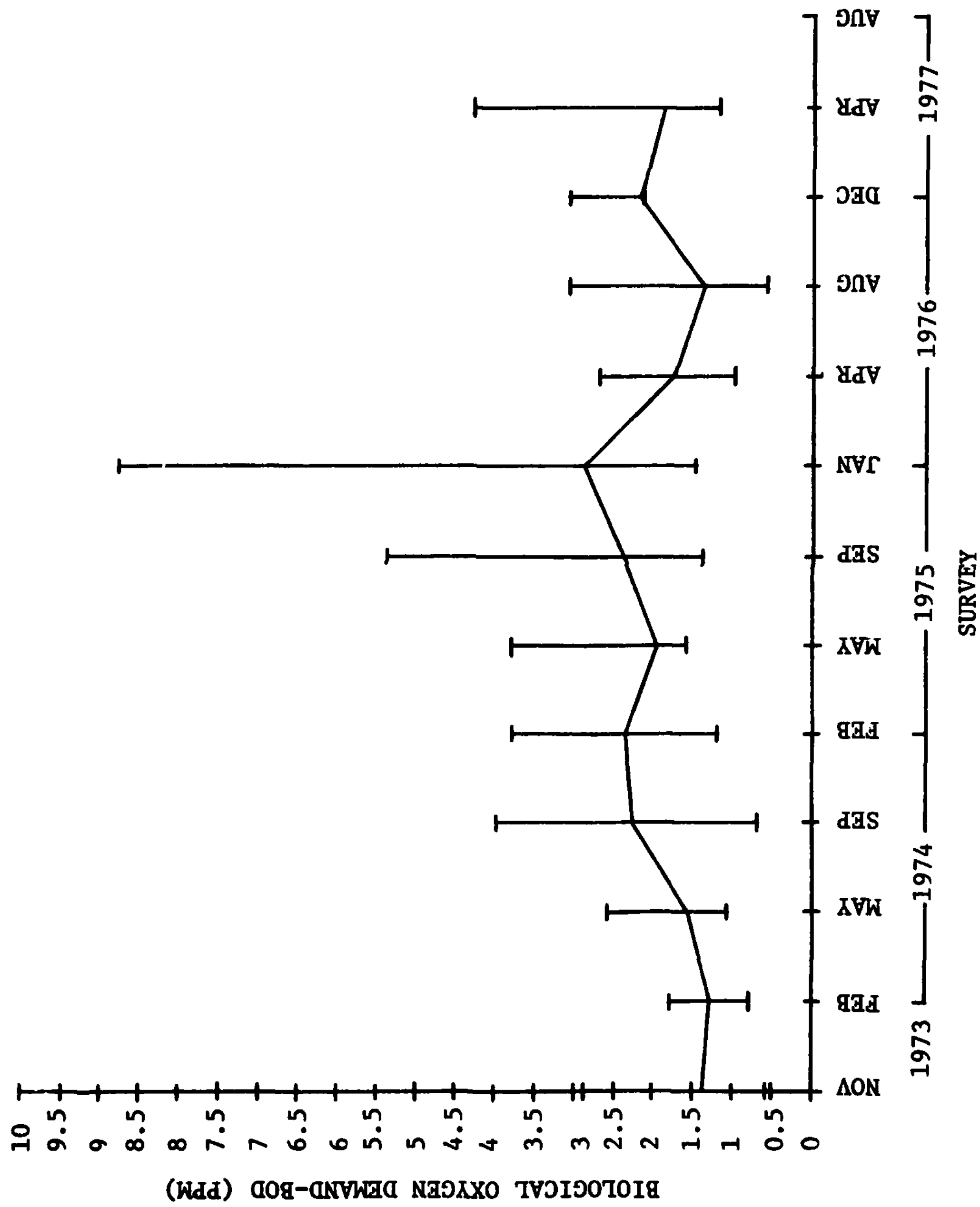

FIGURE A8. BIOLOGICAL OXYGEN DEMAND

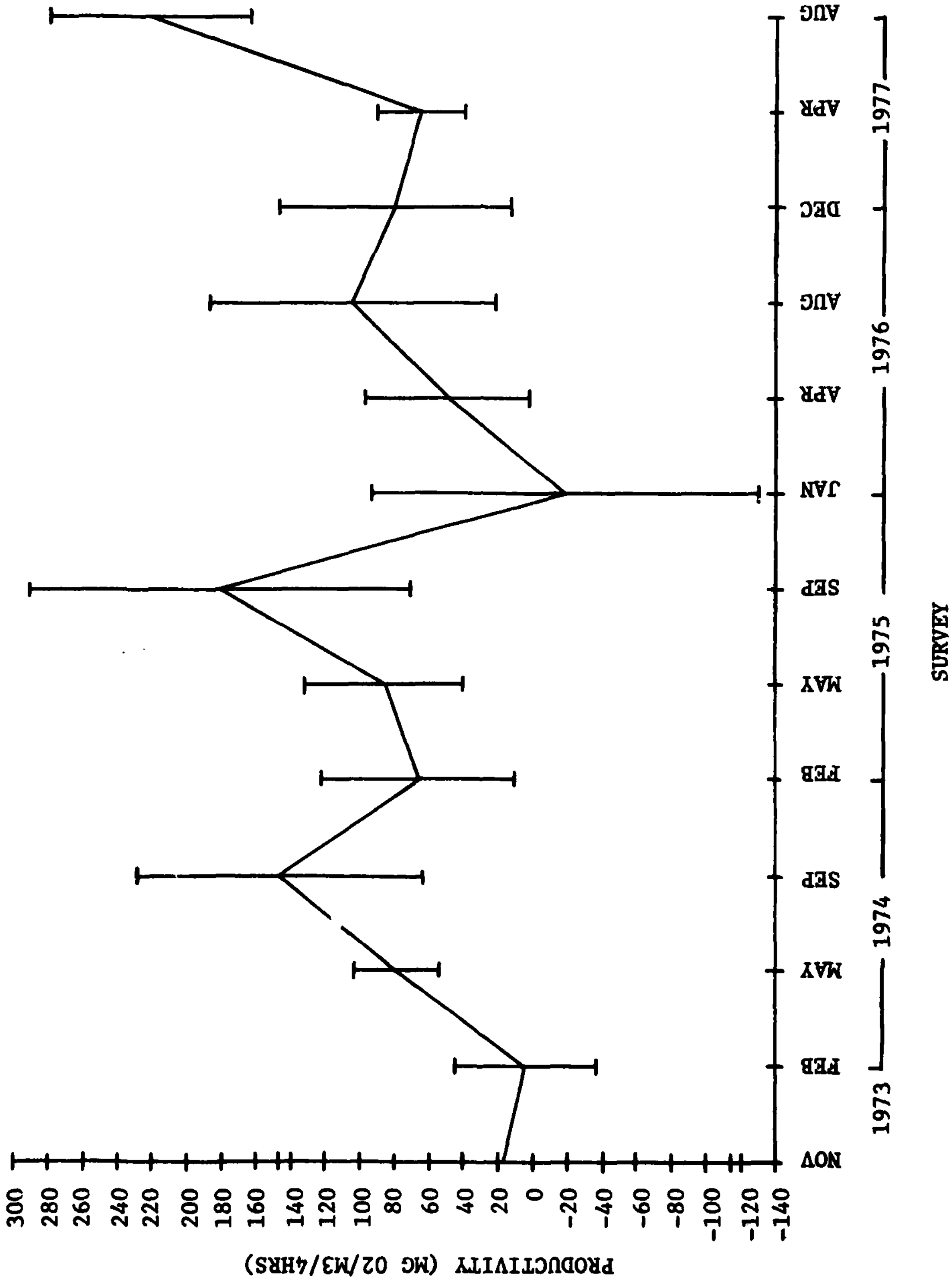

FIGURE A9. PRODUCTIVITY

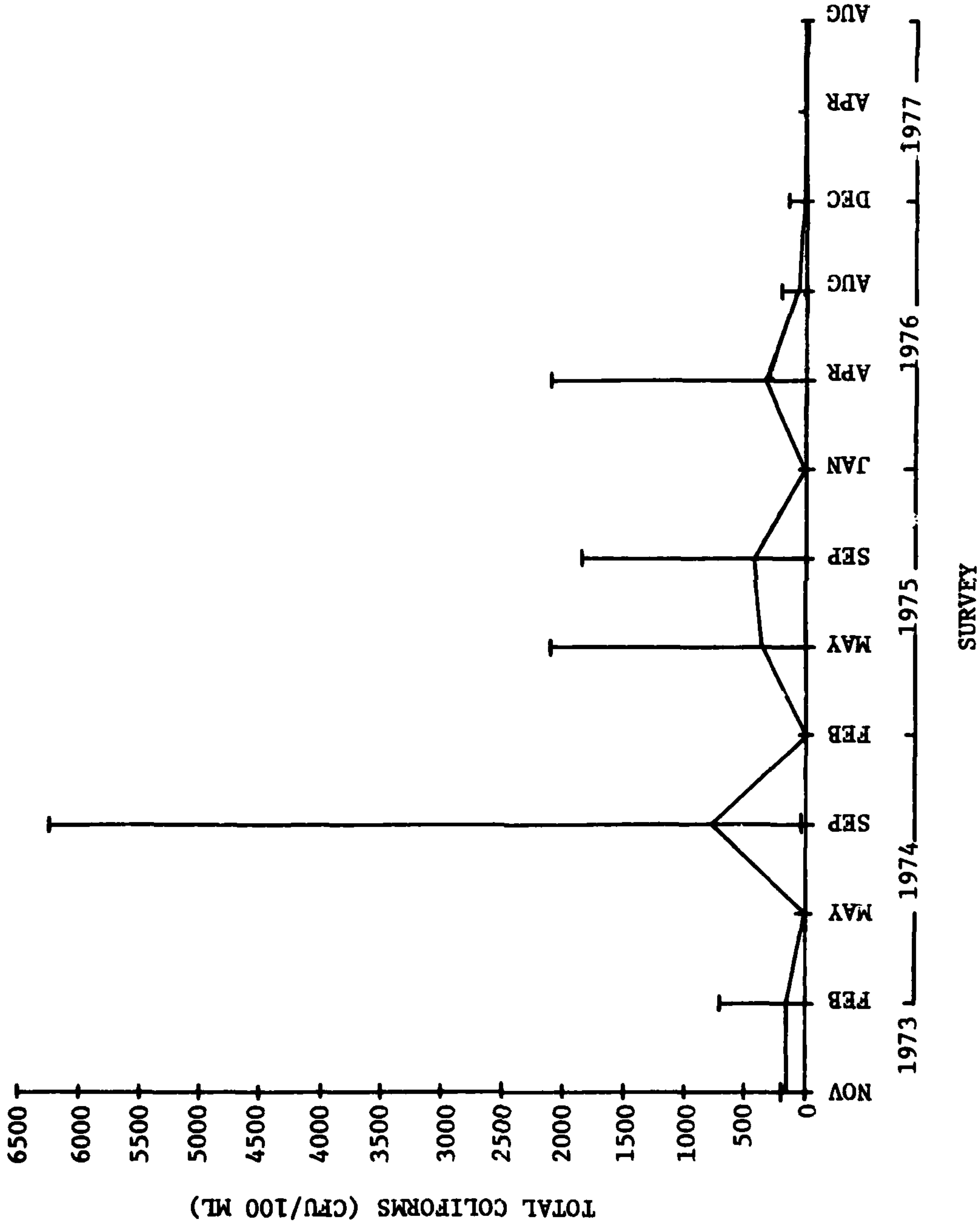

FIGURE A10. TOTAL COLIFORMS

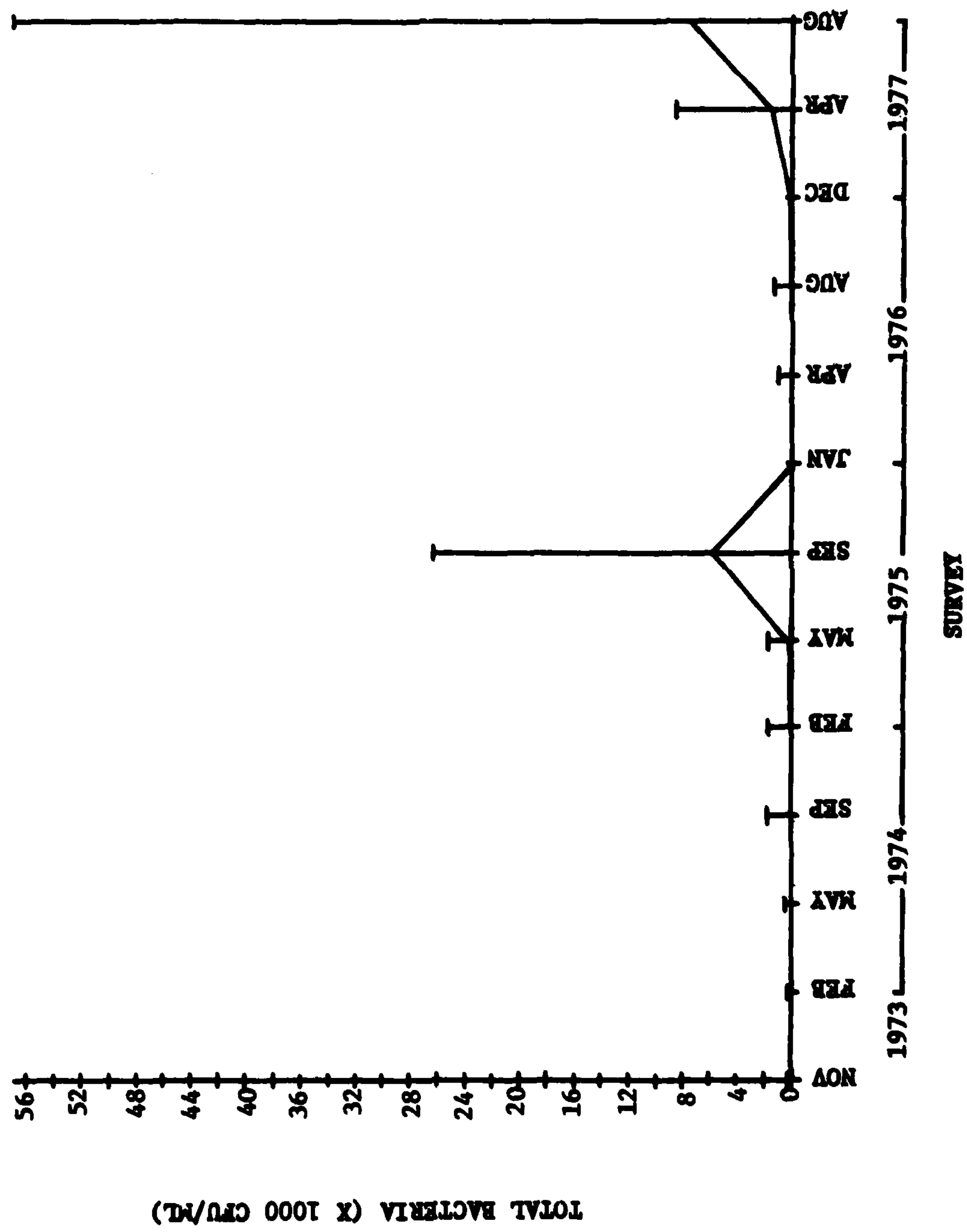

FIGURE A11. TOTAL BACTERIA

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